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DOES PHASE-MODULATION OF APPLIED 40-Hz TRANSCEREBRAL MAGNETIC FIELDS AFFECT SUBJECTIVE EXPERIENCES AND HYPNOTIC INDUCTION?[1]

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Summary.—12 men and 12 women were exposed to a sham-field, a 5-Hz sine-wave magnetic field, a 40-Hz sine-wave magnetic field, or the latter field-phase modulated five times per sec. (5-Hz) for 30 min. between two administrations of the Spiegel's Hypnotic Induction Profile. To replicate the geometry that has produced significant increases in these scores in previous studies, the weak (1 microT) magnetic fields were applied over the right parietotemporal region through a modified helmet. The hypothesis that the enhanced suggestibility previously observed was due to an intrinsic phase-modulation of the fields was not supported. However, the ratings of overall pleasantness of the experiences were negatively correlated ($r = -.36$) with global geomagnetic activity at the time of the experiment. The pleasantness was ranked significantly greater by subjects exposed to the 40-Hz field (explaining 41% of the variance) relative to subjects exposed to the 5-Hz field who also reported more visual experiences within their left peripheral visual fields. The percentages of time alpha rhythms were measured over the temporal lobes (but not frontal or occipital lobes) during the treatments were moderately and positively correlated with scores on questionnaires administered before the experiment, from which the capacity to imagine, temporal lobe signs, and religious (but not exotic) beliefs were inferred. The groups exposed to either the 5-Hz or 40-Hz/5-Hz phase-modulated field displayed greater durations of alpha rhythms over the temporal lobes than the other two groups.

Application of weak (1 microTesla) temporally asymmetric magnetic fields over the right hemisphere during the 20-min. to 30-min. period between two administrations of Spiegel and Spiegel's Hypnotic Induction Profile (1978) have resulted in increased suggestibility (Persinger, 2003). The effect size for the differences between subjects exposed to the magnetic fields and those exposed to the sham-field (all procedures identical except no field was activated) accommodated about 30% of the variance in the change in the scores. We hypothesized that the increases in hypnotic induction following the brief exposures to the specific pattern of magnetic fields were due to their intrinsic phase-modulations. They are embedded within the temporally asymmetric fields denoted as "burst-firing" and "frequency-modulated" (see Persinger, 2003, for diagrams). Phase-modulation was considered an impor-

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tant feature because it may be important for the production of human consciousness (Llinas & Pare, 1991).

The *transcerebral* magnetic stimulation we employed in this and other studies (Baker-Price & Persinger, 1997, 2003) differs significantly from Transcranial Magnetic Stimulation (Wassermann & Linsanby, 2001). The latter involves very simple wave patterns or pulses produced at intensities in the order of a Tesla (a million times stronger). In addition, the magnetic fields for Transcranial Magnetic Stimulation are applied topically through a toroidal geometry while our fields are generated through the brain along the horizontal plane within the level of the temporoparietal lobes.

Method

To test our hypotheses, groups of 12 men and 12 women from a first-year university psychology course were given 2% bonus marks to participate. Between November 2002 and March 2003, they were randomly assigned to one of four conditions. Between the first and second administration of the Hypnotic Induction Profile (Spiegel & Spiegel, 1978) by the first author, each subject was singly exposed for 30 min. to a sham field, a 40-Hz sine-wave field, a 5-Hz sine-wave field, or a 40-Hz field whose phase was modulated five times per sec.

We hypothesized that, if the enhanced suggestibility scores observed in several previous studies following application of complex magnetic fields over the right hemisphere were due to their intrinsic phase-modulation and not their asymmetric temporal patterns, then phase-modulated, symmetrical (sine-wave) magnetic fields should also increase the suggestibility scores. The specific frequencies were chosen, given our theoretical assumptions (Persinger, 1999) and the empirical observations of Llinas and Pare (1991). If phase-modulation *per se* was also the critical component that mediated the hedonistic subjective experiences frequently reported by volunteers exposed to the asymmetric weak, complex magnetic fields, then the subjects exposed to the 40-Hz, 5-Hz phase-modulated fields should report the strongest subjective "pleasantness" compared to other groups.

Our previous studies have also shown that the intensity of global geomagnetic activity at the time of the experience was correlated positively (with a threshold of about 20 nT) with vestibular experiences (Persinger & Richards, 1995) and negatively with pleasantness (Persinger, Richards, & Koren, 1994). Because we expected the "geomagnetic factor" to be present and perhaps even to interact with our experimental treatment, we decided to remove the variance in the scores of pleasantness associated with global geomagnetic activity. The 3-hr. planetary K values, measures of the intrinsic of geomagnetic activity, were obtained from a WEB site (www.dxlc.com/solar/indices.html, prepared by Jan Alvestad) for the 3-hr. periods before, during,

and after each subject was tested. The mean and standard deviation for the 3-hr. Kp value during the intervals of the ratings of the experiences were 2.7 and 1.0, respectively.

To accommodate larger increments of time (daily averages) that might affect more prolonged states, such as "mood," of the subjects, A-values for 24-hr. periods of geomagnetic activity for the day before, the day of, and the day after the exposures were also obtained. The A-values are measures of the variations in the intensity (that can be transformed to nanoTeslas) of the earth's magnetic field. The mean and the standard deviation for the average of the maximum and minimum planetary A value for the days of the experiment in this study were 18.6 and 7.3, respectively.

There were three men and three women per treatment. During the exposure to the treatments, bipolar electroencephalographic activity was measured from the frontal (F7, F8), temporal (T3, T4), and occipital (O1, O2) regions by a Grass P79 unit. The shapes of the magnetic fields were created by converting a column of numbers, each between 0 and 255, to voltage. The time each value (and voltage) was activated was called the point duration. In the experiment all point durations were 3 msec. If one imagines the vertical axis with values between 0 and 255 and the horizontal axis as a series of integers between 1 and any number, then any shape can be generated (Persinger, 2003).

The phase-modulated field was created by increasing the trough time for each successive wave by 3 msec. for four successive point durations and then reducing these values to the original value for five complete cycles per sec., without substantially changing the area (energy) under each curve or its shape. All fields were generated by computer software and delivered through a custom constructed helmet while the subject sat blindfolded in a comfortable chair within a completely darkened acoustic chamber. Presence of the magnetic field was verified by instrumentation for each subject.

Immediately after the exposure and the second administration of the Hypnosis Induction Profile each subject rated the incidence (none, at least once, frequently) for 20 specific experiences (Persinger, 2003) and 12 no–yes items. An overall pleasantness rating scale (–2, –1, 0, +1, +2) for the overall experience was also completed. The electroencephalographic records were scored by examining the numbers of seconds containing alpha (8 Hz–13 Hz) rhythms over the prefrontal, temporal, and occipital regions for 40 successive sec. at 10 min., 20 min., and 30 min. after the beginning of the field treatments. The percentage of alpha seconds for this 2-min. period was the mean of these three values for each of the three brain regions.

To evaluate construct validity of our electroencephalographic measures and the reliability of our observations over experiments, the subjects' scores for the clusters of items from the Personal Philosophy Inventory (Persinger

& Makarec, 1993) and the scores for the Dissociative Experience Scale (Bernstein & Putnam, 1986) and Wilson-Barber's Imaginings scale (Wilson & Barber, 1983) were obtained from data collected in class during September 2002. The latter two scales were employed given their frequent use in clinical settings to infer the two conditions most associated with "hypnosis," the capacity to dissociate and to imagine. The mean and standard deviations for the Imaginings scale (addition of all 0,1 scores) were 23 and 7; these values for the Dissociative Experience Scale were 19 and 9.

The experience-based scale selected from the Personal Philosophy Inventory was for temporal lobe sensitivity (Makarec & Persinger, 1990). The subjects' mean and standard deviation were 39% and 13%, respectively. The two belief scales were for traditional religious beliefs ($M=21\%$, $SD=10\%$) and exotic beliefs ($M=48\%$, $SD=21\%$). The test-retest reliability for the temporal lobe sensitivity scale was .90 for 10 days and about .70 for 100 days. On the basis of the results from Makarec and Persinger (1990), we predicted that the percentage of alpha seconds over the temporal lobes but not the frontal or occipital lobes would be correlated significantly with the scores for temporal lobe sensitivity.

Three-way analysis of variance with one within-subject (score 1 at baseline, score 2 after treatment) and two between-subject (field type, sex) levels showed no statistically significant differences in the mean scores for the Hypnosis Induction Profile for subjects exposed to the different patterns of magnetic fields ($F_{3,15}<1.00$). The interaction between types of magnetic fields and test-retest was not statistically significant ($F_{3,15}=1.35$, $p>.05$). The means and standard deviations for the first and second scores were 6.3 (2.9) and 6.3 (3.1). The means and standard errors of the means for the net change in the scores after the four treatments are shown in Table 1.

These results did not support the hypothesis that elevated scores for the Hypnotic Induction Profile, noted in previous studies, was strongly affected by the intrinsic phase-modulation of the fields. We then analyzed any potential treatment effects on the various types of subjective experiences and ratings of general pleasantness. The significant means and standard deviations of the percentages of yes responding for the various items statistically are shown in Table 1. Two-way analysis of variance indicated a significant difference between treatments ($F_{3,15}=5.77$, $p<.01$; $\eta^2=.61$). *Post hoc* analysis indicated that subjects exposed to the 40-Hz field rated the experience significantly more pleasant than those exposed to the 5-Hz field. This result did not support the hypothesis that phase-modulation was the primary source of the pleasant experiences.

A treatment effect ($F=3.84$, $p<.05$; $\eta^2=.30$) for "odd sounds" was due to the greater frequency reported by the groups exposed to the 5-Hz and 40-Hz fields compared to those exposed to the sham-field or 40-Hz, 5-Hz

TABLE 1

MEANS AND STANDARD ERRORS OF THE MEAN FOR NET CHANGES IN HYPNOTIC INDUCTION PROFILE SCORES AFTER TREATMENT, RATING OF EXPERIENCES, AND PERCENTAGES OF ALPHA SECONDS PER MIN. FOR SUBJECTS EXPOSED TO FOUR FIELD CONDITIONS, AND PERCENTAGES OF AFFIRMATIVE RESPONSES TO OTHER ITEMS

Variable	Sham		5 Hz		40 Hz		40-Hz–5-Hz Phase	
	M	*SEM*	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*
Change in HIP	–0.8	.7	–0.3	.2	–0.2	.7	1.0	.8
Pleasantness	1.2	.3	.5[a]	.3	1.8[b]	.2	.8	.3
Odd sounds	0.6[b]	.3	1.7[a]	.3	1.4	.3	.3[b]	.2
Mean incidence of all experiences	.3	.1	.5	.1	.6	.2	.4	.1
Percentage alpha, sec.								
Occipital lobes	7.9	2.6	37.8	13.2	9.0	7.6	34.1	13.1
Temporal lobes	3.4	1.6	28.8	12.8	11.1	7.7	24.2	10.6
Frontal lobes	1.1	.7	1.0	.6	0.0	0.0	2.2	1.5
Visual Effects	% Yes		% Yes		% Yes		% Yes	
Left side	16		83		16		0	
Right side	0		0		16		0	
Sexual arousal	0		0		0		50	

[ab] $p < .05$.

phase-modulated fields. Visual experiences were primarily along the left side for the group exposed to the 5-Hz field in comparison with all other treatments ($\chi_3^2 = 9.90$, $p < .01$; $\phi = .69$), while there were no treatment differences for visual sensations along the right side. A significantly ($\chi^2 = 7.48$, $p < .05$; $\phi = .58$) greater proportion of the group exposed to the 40-Hz, 5-Hz phase-modulated field reported sexual arousal.

The percentages of alpha seconds per min. over the occipital, temporal, and frontal lobes for the subjects exposed to the different treatments are also shown in Table 1. There were no statistically significant differences between the treatments (all *df*s = 3,20) for the percentage of alpha rhythms over the occipital ($F = 2.44$), temporal ($F = 1.72$), or frontal ($F = .88$) lobes. Kruskal-Wallis, computed given the intergroup heterogeneity of variance, indicated a statistically significant difference between groups ($\chi^2 = 8.94$, $p < .05$) for the percentage of alpha activity over the temporal lobes. The mean values indicated the groups who received the 5-Hz or 40-Hz, 5-Hz modulated magnetic fields displayed more alpha rhythms than the sham-field exposed group. After initial covariance for scores for the temporal lobe signs, the proportion of alpha differed significantly between the groups ($F_{3,16} = 3.06$, $p = .05$; $\eta^2 = .59$). *Post hoc* analysis of the statistically significant differences ($F_{3,16} = 4.56$, $p < .01$; $\eta^2 = .66$) between groups for the square root transformation of the alpha time (after covariance for the scores for the temporal lobe signs) verified the significantly longer periods of alpha rhythms over the tem-

poral lobes for the groups exposed to the 5-Hz or 40-Hz, 5-Hz modulated field compared to the sham-field controls.

Spearman correlations indicated statistically significant associations between only the percentages of alpha activity over the temporal lobes but not the frontal or occipital lobes and the scores for the Imaginings scale (.41), the temporal lobe scale (.44), and religious beliefs (.55) but not the Dissociative Experience Scale (.27) or the exotic belief cluster (.32). These results are similar to previous experiments (Makarec & Persinger, 1990). The scores for the Dissociative Experience Scale (.57) and exotic beliefs from the Personal Philosophy Inventory were also correlated significantly (.57) with the net changes in the Hypnotic Induction Profile scores during the session.

When we employed the measures for geomagnetic activity as covariates for various times before, during, and after the experiences, only the geomagnetic activity at the time of the rating of the experience was significant ($F = 5.72$, $p < .05$) and negatively correlated ($r = -.36$) with the pleasantness ratings. Together both the experimental parameters and the concurrent geomagnetic activity explained 53% (multiple $r = .73$) of the variance in the scores for rating pleasantness.

A comparable, weak but statistically significant negative correlation ($rho = -.40$, $r = -.30$) between the amount of geomagnetic activity during the time of day of the ratings of the pleasantness of the experiences was reported previously (Persinger, *et al.*, 1994). For both this and the previous study pleasantness ratings were also negatively correlated with the geomagnetic activity during the 24-hr. interval of the rating of the experience ($rho = -.36$, $-.35$, respectively) but not with the activity on the days before or after the rating.

There was no evidence that this specific phase-modulated component in the applied field may have been responsible for the enhanced suggestibility noted in previous studies. However, these fields were temporally symmetric (sine-waves). Phase-modulation within the temporally asymmetric fields may be required to simulate the effect. The reliability and validity of our general approach were supported by the replication of positive associations between scores for temporal lobe sensitivity and alpha activity over the temporal lobes, the association of moderate strength between dissociative experiences (measured weeks previously) by paper-and-pencil tests and the actual change in hypnotisability within an experimental setting, and the negative correlation between the pleasantness of the overall experience and geomagnetic activity at the time of the experience.

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